Journal of Herpetology, Vol. 46, No. 4, 442–450, 2012

Uncovering Salamander Ecology: A Review of Coverboard Design

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Abstract.—**Coverboards have been used for decades in research on amphibians and reptiles, but their characteristics have varied widely. This diversity in design may both complicate comparisons among studies and preclude assessment of how coverboards could be deliberately tailored to specific study objectives. Although numerous studies have evaluated the effectiveness of various aspects of coverboards, a general synthesis of these results as they relate to salamanders is lacking. Here, I summarize and evaluate information relating to coverboard design and potential concerns for using coverboards in studies of salamanders.**

Many techniques exist for amphibian ecology, monitoring, and conservation (reviewed by Heyer et al., 1994; Dodd, 2010). Coverboards have been used in salamander surveys for over half a century (Stebbins, 1954; Taub, 1961), and the use of this technique has risen in frequency since reports of its advantages in the early 1990s. Coverboards require a relatively small investment of time and resources to establish and maintain, induce little risk to the animals being monitored, require relatively limited training to implement and monitor (although species identification may require additional training), reduce between-observer variability in data collection, result in low levels of disturbance to habitats, and allow cover objects to be standardized in number and size (DeGraaf and Yamasaki, 1992; Grant et al., 1992; Fellers and Drost, 1994).

Interest in monitoring amphibian populations has also risen following their noted declines worldwide (e.g., Wake, 1991). Salamanders in particular have been promoted as especially good candidates for monitoring ecosystem health and assessing silvicultural practices (e.g., Corn and Bury, 1989; Welsh and Droege, 2001; Davic and Welsh, 2004; Welsh and Hodgson, 2008; but see Kroll et al., 2009; Corn, 2010; Kerby et al., 2010). In comparison with other monitoring methods, coverboards have generally been shown to be comparable or superior. Relative to leaf litter quadrat searches and transects, censuses of coverboards produced greater numbers of captures and lower sampling variability (Monti et al., 2000; Hyde and Simons, 2001). Coverboards also yielded a similar diversity of species in comparison with drift fence/pitfall trap arrays (Bonin and Bachand, 1997), transect searches (Harpole and Haas, 1999), and grids of natural cover (Houze and Chandler, 2002).

Although coverboards may be an important tool in continued studies of salamanders, the variation in coverboard design in published studies may pose a problem for two reasons. First, if salamanders respond differentially to different designs, comparisons among studies may be complicated. Second, variation in design makes evaluation of those potential effects difficult. Without data on the effects of characteristics such as material, spacing, and weathering time, specialized guidelines for addressing specific research questions (e.g., movement, territoriality, activity patterns, occupancy, population genetics) are not possible. The aim of this review is to summarize the available information on the use of coverboards with salamanders, highlighting recommended methods, gaps in knowledge, potential concerns, and directions for further research.

DOI: 10.1670/10-220

Coverboards

Materials.—Of the 11 identified materials used in published salamander coverboard studies (Appendix 1), less than half have been used in more than one study: engineered wood (hereafter collectively referred to as plywood), pine, tin, hemlock, and sugar maple. Available data on numbers of salamanders encountered beneath different materials suggest that salamanders may not use all materials equally.

Plywood coverboards yielded significantly fewer *Plethodon ocmulgee* and *Eurycea cirrigera* than did natural cover in one study (Houze and Chandler, 2002) and no salamanders at all in another (McDade and Maguire, 2005); both reports noted that the soil beneath the plywood coverboards was usually dry, even after several inches of rain. In a study comparing pine and plywood coverboards, Carfioli et al. (2000) reported that the latter tended to create a patch of warm, dry soil in the center of the covered area (although the effects of material and size were confounded in that study). In comparison with tin coverboards, plywood was used to a greater extent by *Ambystoma talpoideum*, *Ambystoma opacum*, *Plethodon glutinosus*, and *Eurycea quadridigitata*, although the boards rotted within three years (Grant et al., 1992).

The use of treated wood for coverboards has generally been avoided, probably because of concerns about the effects of chemicals on amphibians and their prey (e.g., Davis, 1997). The only study to have reported using treated wood (Hampton, 2007) found that treated plywood coverboards were used by three species of pond-breeding salamanders (*A. opacum*, *Ambystoma texanum*, and *Notophthalmus viridescens*) with about the same frequency as corrugated tin coverboards.

Pine coverboards yielded numbers of *Plethodon cinereus* approximately twice as high as natural cover (Taub, 1961), and mean numbers of *P. cinereus* under pine coverboards and natural cover were correlated across three different ages of forest stands (DeGraaf and Yamasaki, 1992). Hemlock coverboards yielded significantly higher encounter rates of *P. cinereus* than asphalt shingles only in stands dominated by eastern hemlock (*Tsuga canadensis*); there was no difference in mixed deciduous stands (Mathewson, 2009). The use of native sugar maple (*Acer saccharum*) coverboards has also been reported to yield high encounter rates of *P. cinereus* (Moore, 2005).

Counts of *P. cinereus* were lower under cedar shingles than under natural cover (Monti et al., 2000). Marsh and Goicochea (2003) suggested that cedar may repel arthropods; thus, cedar coverboards might be avoided by salamanders seeking cover objects as foraging sites. Squares of carpet provided lower encounter rates of *Plethodon albagula* than did wood and degraded within two years (Scheffers et al., 2009). Bonin and

Bachand (1997) suggested the use of plastic coverboards and artificial sponges to reduce variability in the aging and microclimate characteristics of coverboards, but to my knowledge this design has not been tested.

Dimensions of Coverboard.—The size of a cover object may influence the microhabitat conditions available beneath it (e.g., Test and Bingham, 1948). Most salamanders are dependent on cool, moist conditions (Spotila, 1972; Feder, 1983; Grover, 2000); thus, the effect of coverboard dimensions on microhabitat conditions is an important consideration in coverboard design.

Pine or fir at 5-cm thickness is reported to retain moisture better and provide a more stable thermal environment than 0.5-cm plywood, with no additional advantages from 10-cm-thick boards (Fellers and Drost, 1994). Daily temperature fluctuations are also greater under 2-cm plywood coverboards (10°C) than under natural cover objects (3°C) (Houze and Chandler, 2002). Soil temperatures beneath small (11 × 11 cm) 2-cm pine boards did not differ from the surrounding leaf litter, whereas larger (23 × 24 cm) boards were significantly cooler than both; *P. cinereus* were found only under the larger boards (Mathis, 1990). In a comparison of pine and plywood (Carfioli et al., 2000), the coolest and wettest microhabitats were found under large pine boards (106.7 × 17.8 cm), and the warmest and driest microhabitats were found under extra-large plywood boards (121.9 × 61.0 cm). However, board size was not significant as a main effect in a linear model of encounter rates of *P. cinereus*, in which size had higher encounter rates that varied with both transect and season.

Age and Weathering.—The effects of array age and coverboard weathering are difficult to distinguish in many studies. Boards may be weathered for a period of time (or not at all) prior to being deployed, and once deployed, the arrays may be left to weather in place for a period of time before data collection is initiated. Although it has been suggested that older, weathered boards are preferred by salamanders (e.g., Bonin and Bachand, 1997), the only available data indicate no difference in encounter rates for either *P. cinereus* or *Desmognathus fuscus* under new boards (weathered 2 weeks) and old boards (weathered 2–3 yr) (Carlson and Szuch, 2007).

Several multiyear studies report different numbers of salamanders encountered each year (Grant et al., 1992; Davis, 1997; Brooks, 1999, 2001), whereas others show no change in salamander numbers over time (Monti et al., 2000; Houze and Chandler, 2002; Moore, 2005). In such studies, it is generally not possible to determine whether differences in weather conditions, aging of boards, or the duration of coverboard deployment are responsible for the differences in salamander numbers. Environmental conditions may have a strong influence on counts of salamanders (e.g., Fellers and Drost, 1994) and should not be overlooked in studies comparing multiple years. A larger point is that counts of salamanders (index values) are potentially biased by variation in detection probabilities (Hyde and Simons, 2001; Corn, 2010); the use of analytical frameworks that explicitly incorporate detection has been a recent and rarely employed development in studies of salamanders (e.g., Bailey et al., 2004; Dodd and Dorazio, 2004; Mazerolle et al., 2007).

Placement with Respect to Ground.—Carlson and Szuch (2007) reported significantly higher encounter rates of *P. cinereus* under coverboards placed on bare soil, in comparison with coverboards placed on leaf litter. Coverboard age was confounded with placement in that comparison, and a second study showed no difference in encounter rates when boards of different ages were placed directly on the soil. Placing coverboards on leveled ground reduces moisture loss during repeated sampling, because they are more easily repositioned flush with ground (Marsh and Goicochea, 2003).

Several studies have placed coverboards in or over holes in the ground, either to provide better access to moister soil (Monti et al., 2000; Jaeger et al., 2001; Gillette, 2003) or to attempt to sample fossorial species (Bonin and Bachand, 1997). The latter study compared single raised coverboards and stacks of 2, 3, or 4 coverboards placed in holes. The greatest numbers of *P. cinereus* were found in installations with 4 coverboards stacked in a hole, but single raised boards on the surface yielded more than twice as many captures as stacks of 3 coverboards in a hole. The results of Bonin and Bachand (1997) are difficult to interpret, and as yet there has been no direct evaluation of salamander encounter rates for coverboards in or over holes in comparison with coverboards placed flat on the ground.

A few studies in addition to Bonin and Bachand (1997) have used boards that were raised above the surface, either alone (Carfioli et al., 2000) or in stacks (Davis, 1997; McDade and Maguire, 2005). In comparison with coverboards that were placed flat on the leaf litter, those raised on one edge yielded 14.6% fewer encounters of *P. cinereus* (Carfioli et al., 2000). Stacks of 2 coverboards, propped up by 2-cm pieces of wood, yielded no salamanders over the duration of a 7-month study (McDade and Maguire, 2005). However, the effectiveness of raised boards may depend both on design and target species. The coverboards used by Davis (1997) created wedge-shaped spaces between pieces of lumber; all *Ensatina eschscholtzii* and most *Plethodon vehiculum* and *Taricha granulosa* were found underneath the boards, whereas nearly all *Aneides ferreus* were found between the pieces of wood.

Sampling Frequency.—Marsh and Goicochea (2003) found no difference in numbers of *P. cinereus* under coverboards checked weekly and triweekly but significantly fewer under boards checked daily. Similarly, encounter rates of *P. cinereus* declined with each census when coverboards were surveyed three times in one week (Bonin and Bachand, 1997).

Number and Spacing of Boards.—Little research has been done on the effects of array size and coverboard density on salamander encounters. If coverboards are to be used for gathering movement data, spacing of boards gains extra importance. Fellers and Drost (1994) suggested that large grids (100 or more boards) would be necessary for reliable data on individual movements; Willson and Gibbons (2010) suggest conducting a power analysis to determine the number of coverboards necessary to achieve the appropriate sample size (based on preliminary counts of salamander abundance) for a given statistical analysis.

Coverboard placement may also influence the social dynamics of salamanders that use them because of differences in individual movement distances. Gillette (2003) reported that it was not uncommon for individual *P. cinereus* in Virginia to move between boards separated by 1 m, but only 1.9% of adults moved between boards separated by 4 m or more. *Plethodon cinereus* also showed no difference in movement between boards with finer-scale spacing (adjacent, 5 cm, or 1 m) (Schieltz et al., 2010). However, male salamanders did not co-occur beneath adjacent boards in that study, and male–female pairs shared the same board more often when board pairs were closer.

Preventing Disturbance to Arrays.—Several different designs have been used to keep boards immobile: placing a rock on each board after positioning it (Stewart and Bellis, 1970), holding boards in place with aluminum tent stakes (Carlson and Szuch, 2007), and securing boards to the ground by pounding metal rods through holes drilled in the corners of the boards and fastening them with wing nuts (Gillette, 2003). No study has experimentally compared the effectiveness of these techniques.

Potential Concerns for Salamander Coverboard Studies

Disproportionate Usage by Different Age or Size Classes.—One major concern over the use of coverboards is whether individuals found beneath artificial cover are a representative sample of the larger population. Hyde and Simons (2001) determined that members of the *Desmognathus imitator* complex under small boards (26 × 13 cm) were significantly smaller than individuals under large boards (26 × 26 cm). Similarly, permanently removed *P. cinereus* were replaced by significantly smaller individuals (suggesting exclusion by the larger individuals) (Mathis, 1990), and the proportions of adult, hatchling, and juvenile *P. cinereus* under coverboards and natural cover varied among seasons (Marsh and Goicochea, 2003).

By contrast, no significant size differences (mass, snout–vent length, or relative tail length, depending on the study) were found for *P. cinereus* relative to the area of coverboards (Moore, 2005), age of coverboards (Carlson and Szuch, 2007), or between coverboards and natural cover (Monti et al., 2000). Similarly, body size did not differ between *P. albagula* under wood or carpet pieces (Scheffers et al., 2009), or between *P. ocmulgee* under natural and artificial cover (Houze and Chandler, 2002). Given the lack of natural history information (including age structure, site fidelity, detectability, natal dispersal, and associations among kin) for many populations, some caution should be used in interpreting causality when different sizes of salamanders are encountered beneath cover objects. Further studies, particularly addressing the availability of natural and artificial cover when using coverboards, could help determine the extent of differential usage patterns across sites, seasons, and species.

Applicability to Diverse Species.—Published studies using coverboards have resulted in encounters of 44 species of salamanders in 3 families (Appendix 2). The most common species in these studies is the Red-Backed Salamander, *P. cinereus*. This taxonomic focus is likely in part attributable to the abundance and broad geographic range of the species, which includes much of eastern North America (Petranka, 1998). Many studies report that *P. cinereus* is the most common species encountered in herpetofaunal surveys, and often the only species providing enough data for analysis (e.g., Bonin and Bachand, 1997; Brooks, 1999, 2001; Harpole and Haas, 1999; Carfioli et al., 2000; Ross et al., 2000; Morneault et al., 2004; Carlson and Szuch, 2007; Maerz et al., 2009).

Although the available data on coverboard design may be skewed toward the biology of *P. cinereus*, other species of salamander may be encountered very rarely under coverboards or very commonly depending on the details of the study (Appendix 2). The effort to optimize coverboard design, location, and placement for additional species may prove fruitful. Examples include structurally complex coverboards that create a variety of microhabitats (Davis, 1997) and a hybrid coverboard design incorporating halved PVC pipe that was developed for use with semi-aquatic salamanders (Luhring and Young, 2006).

Salamander diversity is extremely high in Mexico, Central America, and the southern Appalachians of the eastern United States (Petranka, 1998). However, studies using coverboards to monitor many species are lacking from the literature, and coverboards are absent from the protocol manual *Amphibian Monitoring in Latin America* (Lips et al., 2001). In light of recent declines of salamander populations in both of their centers of diversity (Highton, 2005; Rovito et al., 2009) and the anticipated effects of future climate change (Buckley and Jetz, 2007), much stands to be gained by evaluating the use of coverboards for a greater variety of salamander species. Abundances of different species may vary markedly from site to site (e.g., Grant et al., 1992; Davis, 1997), and careful site selection may be necessary to effectively sample diverse species. Because the data on coverboard design summarized here may be biased by the dominance of *P. cinereus* in the literature, different coverboard characteristics may be more suitable for monitoring other species, and further research is needed to determine what coverboard design features are most appropriate for a greater variety of species.

Summary

Design.—Cedar and plywood may be avoided by salamanders, whereas pine and other solid woods appear to be generally superior. Wood is more effective than are tin and carpet; both carpet and plywood may degrade within 2–3 yr. Treated plywood was shown to be used by salamanders with the same frequency as was tin, and asphalt shingles appear to be effective, although further studies should assess whether chemicals present in these materials have any adverse effect on salamanders or their prey. Although different forms of engineered wood (e.g., plywood, chipboard, and Masonite) may behave differently from one another, the poor performance of those types that have been tested may suggest that engineered woods should be avoided in general. Use of native dominant native wood may be more effective than other materials in certain forest types. To determine the best material to use for a given species and site, further studies should use arrays with multiple materials (e.g., pine, plywood, cedar, and native wood) across different habitat types and seasons.

Plywood coverboards up to 2 cm in thickness exhibit much larger daily temperature fluctuations than does natural cover; 5-cm pine or fir boards provide more thermal stability than does plywood; and 10-cm boards provide no additional advantages. The coolest and wettest conditions can be achieved under appropriately sized boards: temperatures under smaller boards (e.g., 10 × 10 cm) may not differ from the surrounding leaf litter, and larger plywood boards (e.g., 120 × 60 cm) may create warm, dry conditions. Different sizes of boards may affect the age or size classes of salamanders that use them. Further studies should address this possibility with coverboard arrays of differently sized boards, tested over multiple seasons with several different species.

The age of arrays appears to be more important than the age of coverboards themselves. There may be a delay in occupancy by salamanders immediately after boards are placed, but capture rates are likely to vary from year to year even after boards have been weathered in place. The age of a coverboard itself may or may not matter if it is deployed simultaneously with boards of other ages. The effect of coverboard and array age may be very difficult to determine in multiple-year studies because of the confounding influences of array age, board age, changes in microhabitat, and differences in weather. Carefully designed studies and the use of mark–recapture models could help distinguish among these different variables.

Coverboards placed on bare, leveled ground generally result in the highest encounter rates of salamanders, followed by boards placed on existing leaf litter, and then by raised boards (although encounter rates may differ among species). Further studies should evaluate the usefulness of stacking coverboards for different species and the effect of placing coverboards in or over holes.

Sampling coverboards more often than once per week may reduce the number of captures. Apparently very little research has been done on the effects of array size and board density on salamander encounters; available data suggest that movements between boards separated by more than 1 m may be limited, and the spacing of boards may influence which salamanders are encountered because of social dynamics. A few methods have been used to minimize disturbance to arrays, but their effectiveness has not been evaluated.

Comparison with Other Techniques.—Coverboard arrays appear to provide comparable numbers, lower variability, and a similar diversity of species when compared with alternative approaches such as drift fence/pitfall arrays, natural cover transects, quadrats, and leaf litter surveys. Coverboards may undersample some species, but adjusted designs could improve their effectiveness for those species. The effect of available natural cover on the usage of coverboards by salamanders should be studied further. Additional studies comparing efficacy, ease of use, and observer bias among different methods would be valuable.

Potential Concerns.—Coverboards may be used disproportionately by larger or older salamanders of some species. Researchers should consider this possible bias when planning a study, and further research should address temporal and taxonomic patterns in the use of available cover (both natural and artificial) by salamanders, as well as evaluating the behavioral and ecological bases for these patterns.

Although many salamander species have been encountered under coverboards, coverboard design may have been optimized for *P. cinereus*, a terrestrial species found in eastern North America. Altered designs (e.g., material, dimensions, placement, location, or spacing) may prove superior for other species. With reported declines in salamander populations at both of their global centers of diversity, now may be a crucial time to expand the use of coverboards for studies of a wider variety of species. Further work also should evaluate the ability of a given design to address specific hypotheses and study objectives. In future studies, it should be possible to better tailor coverboard designs to the species, site, and study questions at hand.

Acknowledgments.—I thank L. Bailey, S. Droege, K. Lips, J. Maerz, and the Lips Lab at the University of Maryland and Southern Illinois University for feedback on an earlier draft, as well as the Associate Editor and two anonymous reviewers for comments that improved the manuscript. I received support from the University of Maryland through a Summer Research Fellowship from the Department of Biology and a Flagship Fellowship from the Graduate School.

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Accepted: 3 May 2011.

APPENDIX 1. Materials used as coverboards in studies of salamanders.

Material	Number of studies	Source
Unidentified	1	Hyde and Simons, 2001
Unidentified lumber	6	Hendrickson, 1954; Stebbins, 1954; Davis, 1997; Ford and Hampton, 2005; Semlitsch et al., 2007; Scheffers et al., 2009
Pine (*Pinus* spp.)	8	Taub, 1961; Stewart and Bellis, 1970; Mathis, 1990; DeGraaf and Yamasaki, 1992; Carfioli et al., 2000; Jaeger et al., 2001; Gillette, 2003; Morneault et al., 2004
Tar paper	1	Taub, 1961
Asphalt shingle	1	Mathewson, 2009
Plywood chipboard; plywood; chipboard; CDX pine plywood; particle board; treated plywood	9	Grant et al., 1992; Bonin and Bachand, 1997; Carfioli et al., 2000; Houze and Chandler, 2002; Ryan et al. 2002; McDade and Maguire, 2005; Luhring and Young, 2006; Carlson and Szuch, 2007; Hampton, 2007
Galvanized tin; tin; corrugated tin	3	Grant et al., 1992; Ford and Hampton, 2005; Hampton, 2007
Eastern hemlock (*Tsuga canadensis*)	4	Brooks, 1999, 2001; DeGraaf and Yamasaki, 2002; Mathewson, 2009
Tulip poplar (*Liriodendron tulipifera*)	1	Harpole and Haas, 1999
Cedar shingle (*Thuja plicata*?)	1	Monti et al., 2000
White oak (*Quercus alba*)	1	Marsh and Goicochea, 2003
Sugar maple (*Acer saccharum*)	2	Moore, 2005; Maerz et al., 2009
Carpet	1	Scheffers et al., 2009

APPENDIX 2. Salamander species encountered in studies using coverboards.

Species	Study location	Number of encounters	Total salamander encounters	Proportion of species in total salamander encounters (%)	Source
Family Ambystomatidae					
Ambystoma annulatum	Daniel Boone Conservation Area, Missouri	4	310	1.29	Scheffers et al., 2009
Ambystoma laterale	Mont Orford Park, Quebec	9	134	6.72	Bonin and Bachand, 1997
A. laterale	Ontario	24	2208	1.09	Morneault et al., 2004
A. laterale	Kresge Environmental Education Center, Michigan	17	154	11.04	Carlson and Szuch, 2007
A. laterale	Murphy Lake State Game Area, Michigan	3	352	0.85	Carlson and Szuch, 2007
Ambystoma macrodactylum	Greater Victoria Watershed, Vancouver Island (forested sites)	3	–	0–2%	Davis, 1997
Ambystoma maculatum	Mont Orford Park, Quebec	1	75	1.33	Bonin and Bachand, 1997
A. maculatum	Quabbin Reservation, Massachusetts	10	2,387	0.42	Brooks, 1999
A. maculatum	Barkhamsted Reservoir, Connecticut/Massachusetts	8	592	1.35	Brooks, 2001
A. maculatum	Ontario	33	2,208	1.49	Morneault et al., 2004
A. maculatum	Camp Maxey, Texas	1	2	50.00	Ford and Hampton, 2005
A. maculatum	Lapeer County, Michigan	3	154	1.95	Carlson and Szuch, 2007
A. maculatum	Murphy Lake State Game Area, Michigan	6	352	1.70	Carlson and Szuch, 2007
A. maculatum	Nantahala National Forest, North Carolina	1	199	0.50	Semlitsch et al., 2007
A. maculatum	Central New York; northeastern Pennsylvania	–	–	–	Maerz et al., 2009
Ambystoma opacum	Savannah River Site (SRS), South Carolina	25	844	2.96	Grant et al., 1992
A. opacum	Camp Maxey, Texas	1	2	50.00	Ford and Hampton, 2005
A. opacum	Old Sabine Bottom Wildlife Management Area, Texas	1	33	3.03	Hampton, 2007
A. opacum	Daniel Boone Conservation Area, Missouri	1	310	0.32	Scheffers et al., 2009
Ambystoma texanum	Old Sabine Bottom Wildlife Management Area, Texas	30	33	90.91	Hampton, 2007
Ambystoma talpoideum	Savannah River Site (SRS), South Carolina	21	844	2.49	Grant et al., 1992
Family Plethodontidae					
Aneides ferreus	Greater Victoria Watershed, Vancouver Island (forested sites)	5	–	0–2.4	Davis, 1997

APPENDIX 2. Continued.

Species	Study location	Number of encounters	Total salamander encounters	Proportion of species in total salamander encounters (%)	Source
A. ferreus	Rosewall Creek Provincial Park, Vancouver Island	64	–	68.9–87.1	Davis, 1997
Aneides lugubris	Pinehurst Madrone Grove Park, California	–	–	–	Stebbins, 1954
Batrachoseps attenuatus	Pinehurst Madrone Grove Park, California	327	–	–	Hendrickson, 1954
B. attenuatus	Pinehurst Madrone Grove Park, California	–	–	87.50	Stebbins, 1954
Batrachoseps pacificus	Channel Islands, California	–	–	–	Fellers and Drost, 1994
Desmognathus auriculatus	Richmond County, Georgia	1	30	3.33	Luhring and Young, 2006
Desmognathus conanti	Richmond County, Georgia	5	30	16.67	Luhring and Young, 2006
Desmognathus fuscus	Centre County, Pennsylvania	294	399	73.68	Stewart and Bellis, 1970
D. fuscus	Centre County, Pennsylvania	65	130	50.00	Stewart and Bellis, 1970
D. fuscus	White Mountain National Forest, New Hampshire	1	110	0.91	DeGraaf and Yamasaki, 1992
D. fuscus	Mont Orford Park, Quebec	3	75	4.00	Bonin and Bachand, 1997
D. fuscus	Quabbin Reservation, Massachusetts	6	2,387	0.25	Brooks, 1999
D. fuscus complex	Great Smoky Mountains National Park, Tennessee/North Carolina	–	1,224	–	Hyde and Simons, 2001
D. fuscus	White Mountain National Forest, New Hampshire	1	4,050	0.02	DeGraaf and Yamasaki, 2002
D. fuscus	Murphy Lake State Game Area, Michigan	116	352	32.95	Carlson and Szuch, 2007
Desmognathus imitator complex	Great Smoky Mountains National Park, Tennessee/North Carolina	–	1,224	–	Hyde and Simons, 2001
Desmognathus monticola	Great Smoky Mountains National Park, Tennessee/North Carolina	–	1,224	–	Hyde and Simons, 2001
Desmognathus ocoee	Nantahala National Forest, North Carolina	3	199	1.51	Semlitsch et al., 2007
Desmognathus ocrophaeus	Centre County, Pennsylvania	77	399	19.30	Stewart and Bellis, 1970
D. ocrophaeus	Centre County, Pennsylvania	25	130	19.23	Stewart and Bellis, 1970
D. ochrophaeus	Central New York; northeastern Pennsylvania	–	–	–	Maerz et al., 2009
Desmognathus quadramaculatus	Great Smoky Mountains National Park, Tennessee/North Carolina	–	1,224	–	Hyde and Simons, 2001
Desmognathus wrighti	Great Smoky Mountains National Park, Tennessee/North Carolina	–	1,224	–	Hyde and Simons, 2001
Ensatina eschscholtzii	Pinehurst Madrone Grove Park, California	527	–	–	Stebbins, 1954
E. eschscholtzii	Greater Victoria Watershed, Vancouver Island (forested sites)	22	–	4.9–11.9	Davis, 1997
E. eschscholtzii	Rosewall Creek Provincial Park, Vancouver Island	2	–	0–2.1	Davis, 1997
Eurycea bislineata	Somerset County, New Jersey	118	266	44.36	Taub, 1961
E. bislineata	Centre County, Pennsylvania	25	399	6.27	Stewart and Bellis, 1970
E. bislineata	Centre County, Pennsylvania	31	130	23.85	Stewart and Bellis, 1970
E. bislineata	Mont Orford Park, Quebec	15	75	20.00	Bonin and Bachand, 1997
E. bislineata	Mont Orford Park, Quebec	12	134	8.96	Bonin and Bachand, 1997
E. bislineata	Quabbin Reservation, Massachusetts	6	2,387	0.25	Brooks, 1999
E. bislineata	Valley Forge National Historical Park, Pennsylvania	2	952	0.21	Carfioli et al., 2000
E. bislineata	White Mountain National Forest, New Hampshire	7	4,050	0.17	DeGraaf and Yamasaki, 2002
E. bislineata	Barkhamsted Reservoir, Connecticut/Massachusetts	6	592	1.01	Brooks, 2001
E. bislineata	Lake Clair Watershed, Quebec	23	309	7.44	Moore, 2005
E. bislineata	Central New York; northeastern Pennsylvania	–	–	–	Maerz et al., 2009
Eurycea cirrigera	Jenkins County, Georgia	9	43	20.93	Houze and Chandler, 2002
E. cirrigera	Richmond County, Georgia	2	30	6.67	Luhring and Young, 2006
Eurycea guttolineata	Jenkins County, Georgia	1	43	2.33	Houze and Chandler, 2002
E. guttolineata	Richmond County, Georgia	1	30	3.33	Luhring and Young, 2006
Eurycea longicauda	Centre County, Pennsylvania	1	130	0.77	Stewart and Bellis, 1970

APPENDIX 2. Continued.

Species	Study location	Number of encounters	Total salamander encounters	Proportion of species in total salamander encounters (%)	Source
Eurycea quadridigitata	Savannah River Site (SRS), South Carolina	133	844	15.76	Grant et al., 1992
E. quadridigitata	Jenkins County, Georgia	1	43	2.33	Houze and Chandler, 2002
Eurycea wilderae	Great Smoky Mountains National Park, Tennessee/North Carolina	–	1,224	–	Hyde and Simons, 2001
E. wilderae	Nantahala National Forest, North Carolina	2	199	1.01	Semlitsch et al., 2007
Gyrinophilus porphyriticus	Centre County, Pennsylvania	1	399	0.25	Stewart and Bellis, 1970
G. porphyriticus	Centre County, Pennsylvania	3	130	2.31	Stewart and Bellis, 1970
G. porphyriticus	Great Smoky Mountains National Park, Tennessee/North Carolina	–	1,224	–	Hyde and Simons, 2001
G. porphyriticus	White Mountain National Forest, New Hampshire	4	4,050	0.10	DeGraaf and Yamasaki, 2002
G. porphyriticus	Central New York; northeastern Pennsylvania	–	–	–	Maerz et al., 2009
Hemidactylium scutatum	Quabbin Reservation, Massachusetts	1	2,387	0.04	Brooks, 1999
H. scutatum	Murphy Lake State Game Area, Michigan	6	352	1.70	Carlson and Szuch, 2007
H. scutatum	Central New York; northeastern Pennsylvania	–	–	–	Maerz et al., 2009
Plethodon albagula	Daniel Boone Conservation Area, Missouri	303	310	97.74	Scheffers et al., 2009
Plethodon cinereus	Somerset County, New Jersey	145	266	54.51	Taub, 1961
P. cinereus	Centre County, Pennsylvania	1	130	0.77	Stewart and Bellis, 1970
P. cinereus	Mountain Lake Biological Station, Virginia	7	7	100.00	Mathis, 1990
P. cinereus	White Mountain National Forest, New Hampshire	109	110	99.09	DeGraaf and Yamasaki, 1992
P. cinereus	Mont Orford Park, Quebec	56	75	74.67	Bonin and Bachand, 1997
P. cinereus	Mont Orford Park, Quebec	113	134	84.33	Bonin and Bachand, 1997
P. cinereus	Quabbin Reservation, Massachusetts	2,280	2,387	95.52	Brooks, 1999
P. cinereus	George Washington and Jefferson National Forest, Virginia	–	–	–	Harpole and Haas, 1999
P. cinereus	Valley Forge National Historical Park, Pennsylvania	947	952	99.47	Carfioli et al., 2000
P. cinereus	Holt Research Forest, Maine	1,235	1,235	100.00	Monti et al., 2000
P. cinereus	Barkhamsted Reservoir, Connecticut/Massachusetts	556	592	93.92	Brooks, 2001
P. cinereus	Mountain Lake Biological Station, Virginia	67	–	–	Jaeger et al., 2001
P. cinereus	White Mountain National Forest, New Hampshire	4,038	4,050	99.70	DeGraaf and Yamasaki, 2002
P. cinereus	Mountain Lake Biological Station, Virginia	3,733	–	–	Gillette, 2003
P. cinereus	Washington and Lee University, Virginia	–	–	–	Marsh and Goicochea, 2003
P. cinereus	Ontario	2,144	2,208	97.10	Morneault et al., 2004
P. cinereus	Lake Clair Watershed, Quebec	285	309	92.23	Moore, 2005
P. cinereus	Lapeer County, Michigan	130	154	84.42	Carlson and Szuch, 2007
P. cinereus	Murphy Lake State Game Area, Michigan	221	352	62.78	Carlson and Szuch, 2007
P. cinereus	Central New York; northeastern Pennsylvania	–	–	–	Maerz et al., 2009
P. cinereus	Harvard Forest, Massachusetts	444	–	–	Mathewson, 2009
Plethodon cylindraceus	George Washington and Jefferson National Forest, Virginia	1	–	–	Harpole and Haas, 1999
Plethodon glutinosus	Savannah River Site (SRS), South Carolina	665	844	78.79	Grant et al., 1992
P. glutinosus	Central New York; northeastern Pennsylvania	–	–	–	Maerz et al., 2009
P. glutinosus complex	Great Smoky Mountains National Park, Tennessee/North Carolina	–	1,224	–	Hyde and Simons, 2001
Plethodon jordani	Great Smoky Mountains National Park, Tennessee/North Carolina	–	1,224	–	Hyde and Simons, 2001
Plethodon metcalfi	Nantahala National Forest, North Carolina	153	199	76.88	Semlitsch et al., 2007

Appendix 2. Continued.

Species	Study location	Number of encounters	Total salamander encounters	Proportion of species in total salamander encounters (%)	Source
Plethodon ocmulgee	Jenkins County, Georgia	32	43	74.42	Houze and Chandler, 2002
Plethodon oconaluftee	Nantahala National Forest, North Carolina	23	199	11.56	Semlitsch et al., 2007
Plethodon richmondi	Centre County, Pennsylvania	4	130	3.08	Stewart and Bellis, 1970
Plethodon serratus	Great Smoky Mountains National Park, Tennessee/North Carolina	–	1,224	–	Hyde and Simons, 2001
P. serratus	Nantahala National Forest, North Carolina	13	199	6.53	Semlitsch et al., 2007
Plethodon vehiculum	Goldstream Provincial Park, Vancouver Island	–	–	100	Davis, 1997
P. vehiculum	Lake Cowichan, Vancouver Island	168	–	69.70	Davis, 1997
P. vehiculum	Greater Victoria Watershed, Vancouver Island (forested sites)	217	–	72.6–81.3	Davis, 1997
P. vehiculum	Greater Victoria Watershed, Vancouver Island (clearcut site)	15	–	100	Davis, 1997
P. vehiculum	Rosewall Creek Provincial Park, Vancouver Island	17	–	0–29.17	Davis, 1997
Pseudotriton ruber	Somerset County, New Jersey	3	266	1.13	Taub, 1961
P. ruber	Centre County, Pennsylvania	2	399	0.50	Stewart and Bellis, 1970
P. ruber	Great Smoky Mountains National Park, Tennessee/North Carolina	–	1,224	–	Hyde and Simons, 2001
P. ruber	Valley Forge National Historical Park, Pennsylvania	3	952	0.32	Carfioli et al., 2000
P. ruber	Richmond County, Georgia	19	30	63.33	Luhring and Young, 2006
P. ruber	Central New York; northeastern Pennsylvania	–	–	–	Maerz et al., 2009
Family Salamandridae					
Notophthalmus viridescens	Quabbin Reservation, Massachusetts	84	2,387	3.52	Brooks, 1999
N. viridescens	Barkhamsted Reservoir, Connecticut/Massachusetts	22	592	3.72	Brooks, 2001
N. viridescens	Ontario	24	2,208	1.09	Morneault et al., 2004
N. viridescens	Lake Clair Watershed, Quebec	1	309	0.32	Moore, 2005
N. viridescens	Old Sabine Bottom Wildlife Management Area, Texas	2	33	6.06	Hampton, 2007
N. viridescens	Lapeer County, Michigan	4	154	2.60	Carlson and Szuch, 2007
N. viridescens	Nantahala National Forest, North Carolina	3	199	1.51	Semlitsch et al., 2007
N. viridescens	Central New York; northeastern Pennsylvania	–	–	–	Maerz et al., 2009
N. viridescens	Daniel Boone Conservation Area, Missouri	2	310	0.65	Scheffers et al., 2009
Taricha granulosa	Lake Cowichan, Vancouver Island	73	–	30.30	Davis, 1997
T. granulosa	Greater Victoria Watershed, Vancouver Island (forested sites)	30	–	7.7–13.1	Davis, 1997
T. granulosa	Rosewall Creek Provincial Park, Vancouver Island	1	–	0–3.2	Davis, 1997
Taricha torosa	Pinehurst Madrone Grove Park, California	–	–	–	Stebbins, 1954